

Polishing apparatus for planarizing the macroscopically flat surface of a semiconductor material to expose microscopic features which have been formed in the semiconductor material and are below and covered by the macroscopically flat surface of the semiconductor material. The apparatus planarizes the surface of the semiconductor material to within about 100 to 250 Angstroms deviation from the perfectly flat median reference plane of the surface.

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- 1 -

## APPARATUS FOR INTERLAYER PLANARIZATION OF SEMICONDUCTOR MATERIAL

This invention relates to polishing apparatus.

More particularly, the invention relates to polishing apparatus for planarizing the macroscopically flat surface of semiconductor wafer to expose microscopic features which have been formed in the semiconductor wafer and are below and covered by the macroscopically flat surface of the wafer.

In a further respect, the invention relates to semiconductor polishing apparatus of the type described which facilitates the removal at equal rates of areas of hard material and of soft material from the surface of a semiconductor wafer.

Composite pads for polishing semiconductor material are well known in the art. See, for example, U. S. Patent No. 3,504,457 to Jacobsen et al. The Jacobsen patent discloses a composite or multi-layer pad which includes a resilient foam polyurethane polishing layer or film 23, an intermediate resilient Corfam layer 20, and a chemically inert stiffer nitrile rubber layer 35. In the Jacobsen composite polishing pad, the more resilient layers of the pad are adjacent the semiconductor while the stiffer nitrile rubber layer is further from the semiconductor which is being polished. While the resilient pads like the Jacobsen pad have long been utilized and accepted in polishing semiconductor materials, such conventional resilient pad structures do not appear to readily uniformly planarize a macroscopic semiconductor surface which includes microscopic areas which are higher (or lower) than the major global portion of the macroscopic semiconductor surface or which includes areas which are softer than and abrade and flatten more quickly than other harder areas of the semiconductor surface. In particular, conventional pads tend to sit on and round the edges of a high area so the high area takes on the shape of a rounded mound. The planarization of the surface of a semiconductor material is particularly critical during the process of

- 2 -

photolithography. During a typical photolithography process a metal film of aluminum, tungsten, polysilicon, etc. is deposited on a flat semiconductor wafer. A layer of photoresist is sprayed or otherwise applied to the metal film. The photoresist is photoactive. A mask is placed over the photoresist layer and the layer and mask are exposed to light. The areas of photoresist which are not covered by the mask are exposed to the light and harden. The mask is removed. A chemical is utilized to remove the unexposed, unhardened areas of the photoresist. Another chemical is utilized to etch off the unprotected metal which is exposed when the unexposed photoresist is etched off. Still another chemical is then utilized to remove the hardened photoresist from the lines or strips of metal film which remain on the flat semiconductor wafer. After the hardened photoresist is removed, the metal lines or strips which remain on the flat semiconductor wafer typically have a width in the range of about 0.3 to 2.0 microns, preferably in the range of 0.5 to 1.0 microns. The thickness or height of the metallic lines is also in the range of 0.3 to 2.0 microns, preferably 0.5 to 1.5 microns. A coating of silicon dioxide or other metal oxide or other insulating material is then deposited over the metal lines and remaining open areas of the flat semiconductor material. The depth or thickness of the metallic oxide coating is greater than the height of the metal lines, i.e., is greater than the 0.3 to 2.0 micron height of the metal lines. This metallic oxide is polished until the tops of the metal lines are "exposed". Such "exposing" of the metal lines consists of polishing away all the metal oxide on top of the metal lines or of polishing away most of the metal oxide so only a thin layer of metal oxide remains on the metal lines. The metal lines can have a hardness greater than that of the insulating coating which is intermediate the metal lines, in which case the insulating coating tends to be "scoured" out between the

- 3 -

metal lines such that a flat planar surface is not formed during the interlayer dielectric planarization or polishing of the metal line--insulator material. Alternately, the metal lines can have a hardness less than that of the insulating coating which is intermediate the metal lines, in which case the metal lines tend to be "scoured" out when the polishing process is continued after all of the insulating coating is removed from above the metal lines.

While metals or metal-like materials may be deposited on a semiconductor wafer, the primary objective in polishing materials deposited on a semiconductor wafer is in the planarization or flattening of the materials, and not making the materials smoother. In contrast, the primary purpose of polishing metals is typically to make the surface of the metal smooth. The distinction between polishing for the purpose of smoothness and polishing for the purpose of flatness is an important one and affects the characteristics of the polishing apparatus selected. Polishing apparatus which is effective in producing a smooth surface may not be successful in producing the close tolerance flat or planar surfaces required in the production of semiconductor materials.

Accordingly, it would be highly desirable to provide an improved apparatus and method for planarizing semiconductor materials, which apparatus and method would accurately planarize a semiconductor surface comprised of materials which have differing polishing characteristics.

Therefore, it is a principal object of the invention to provide an improved apparatus and method for polishing a material to produce a flat surface.

A further object of the invention is to provide an improved polishing method and apparatus which effectively planarizes within close tolerances the surface of a semiconductor material containing compositions of differing hardness.

Another object of the instant invention is to

- 4 -

provide an improved composite polishing pad which includes layers of material having differing deflection constants and differing moduli of elasticity.

5 Still a further object of the invention is to provide an improved polishing pad which minimizes the effect of hysteresis on the elastic compression and expansion of the pad.

10 These and other, further and more specific objects and advantages of the invention will be apparent to those skilled in the art from the following detailed description thereof, taken in conjunction with the drawings, in which:

15 Fig. 1 is graph illustrating the relationship between the deflection of a polishing pad and the pressure applied to the pad;

20 Fig. 2 is a side view illustrating a semiconductor material with an undulating microscopic surface and a portion of a composite polishing pad utilized to planarize the surface of the semiconductor material;

Fig. 3 is a side section view of portions of the polishing pad and semiconductor material of Fig. 2 further illustrating construction details thereof;

25 Fig. 4 is a side section view of a semiconductor material illustrating the median plane representing the macroscopically flat surface of the semiconductor material;

30 Fig. 5 is a side section view illustrating the compression of the composite polishing pad of the invention as it moves underneath a wafer of semiconductor material;

35 Fig. 6 is a graph representing the pressure of a resilient polishing pad against a semiconductor material in relation to the time elapsed from when the pad first begins to move beneath the semiconductor material;

Fig. 7 is a top view of the polishing pad and wafer carrier of Figs. 2 and 5; and,

- 5 -

Fig. 8 is a section view illustrating an alternate polishing pad construction of the invention.

Briefly, in accordance with my invention, I provide improved apparatus for polishing a piece of material. The piece of material includes a macroscopically flat subsurface; at least a pair of features each connected to the subsurface, each extending a substantially equal distance above the subsurface, and being spaced apart a distance of less than five hundred microns; and, a coat extending over and covering the features and the subsurface. The surface of the coating comprises a work surface which is macroscopically flat and microscopically undulating. The improved polishing apparatus microscopically planarizes the work surface to expose the pair of features and includes polishing pad means. The polishing pad means includes a base; a first layer of resilient material connected to the base and having an outer surface spaced apart from the base and having a deflection constant which is greater than six microns per psi when a pressure in excess of about four psi is applied to the first layer of material; a second layer of resilient material connected to at least a portion of the outer surface, having a polishing surface spaced apart from the outer surface, and having a deflection constant less than the deflection constant of the first layer; and including a colloidal slurry polishing media on the polishing surface of the second layer. The improved polishing apparatus also includes holding means for holding the piece of material with the work surface disposed against the polishing surface; and, motive power means for moving at least one of the polishing pad means and the holding means with respect to the other such that movement of the one of the polishing pad means and the holding means causes the colloidal media and polishing surface to contact and polish the work surface.

Turning now to the drawings, which depict the

- 6 -

presently preferred embodiments of the invention for the purpose of illustrating the practice thereof and not by way of limitation of the scope of the invention, and in which like reference characters refer to corresponding elements throughout the several views, Fig. 1 is a graph illustrating the relationship between the deflection or compression, D, of a resilient pad with respect to the pressure, P, applied to the pad. In Fig. 1, P1 is greater than P2 and D1 is greater than D2. For urethane materials D2 typically will be about 70 microns when P1 is about four psi. The line 13 in the graph includes straight line portion 12 and curved portion 11. As indicated by the graph, for many resilient materials once the pressure acting against the material exceeds a certain pressure, the relationship between the deflection, D, and the pressure, P, applied to the pad is generally linear. The slope of the straight line portion 12 is termed the deflection constant and represents the compression of a pad which occurs with a particular pressure applied to the pad. The curved line portion 11 is probably attributable to the crushing of the surface nap of the pad.

In Fig. 2 a cylindrical piece or wafer of semiconductor material 23 or other material is mounted on a cylindrical polishing head 24. Head 24 has a circular support surface 24A which receives the macroscopically flat circular planar bottom surface 23A of wafer 23. As used herein, the term "macroscopically flat" indicates that a surface appears flat to the human eye. The term "microscopically flat" indicates that a surface appears flat to a human eye aided by a microscope. The upper work surface 23B of wafer 23 is also macroscopically flat and generally parallel to surface 24A. Surface 23B does, on a microscopic level, undulate, simply because no surface is ever perfectly flat. The undulation of surface 23B is small and is in the range of a 0.1 to 4.0 micron deviation from a median plane passing through surface

- 7 -

23B. For example, the distance D5 in Fig. 2 is typically on the order of about two to three microns.

The deviation of the work surface of a semiconductor wafer from the median plane of the wafer is further explained with reference to Fig. 4. In Fig. 4 semiconductor wafer 230 is mounted on cylindrical polishing head 24. The circular planar support surface 24A of head 24 receives the macroscopically flat circular planar bottom surface 230A of wafer 230. The upper work surface 230B of wafer 230 is also macroscopically flat and generally parallel to surface 24A. Surface 230B does, on a microscopic scale, globally undulate. This global undulation is, as it is for surface 23B in Fig. 2, indicated by a curved line representing surface 230B. The undulation of surface 230B in Fig. 4 (and of surface 23B in Fig. 2) is obviously greatly exaggerated for the purposes of this discussion. Dashed line 15 in Fig. 4 represents the median plane for surface 230B. Median plane 15 in Fig. 4 is, but need not be, generally parallel to surface 24A and is perpendicular to the plane of the sheet of paper of the drawings. Median plane 15 intersects surface 230B such that the sum of all distances to points underneath median plane 15 and of all distances to points above median plane 15 is zero. The distances to points beneath plane 15 are treated as negative values while the distances to points above the median plane 15 are treated as positive values. Therefore, in Fig. 4 the distance indicated by arrows G is a negative value while the distance indicated by the arrows F is a positive value. In actual practice, distances such as those indicated by arrows F and G in Fig. 4 are in the range of about 0.1 to about 4.0 microns. Median plane 15 is perfectly flat.

Returning to Fig. 2, polishing pad means 19 includes a cylindrical metal base 20 with a circular planar upper surface 20A. The macroscopically planar bottom surface 21A of resilient pad 21 is attached to

- 8 -

surface 20A, typically with a layer of adhesive. Upper macroscopically planar surface 21B is attached to the lower macroscopically planar surface 22A of flexible pad 22. Adhesive is ordinarily utilized to interconnect surfaces 21B and 22A. The upper polishing surface 22B of resilient pad 22 is generally macroscopically planar. Surfaces 20A, 21A, 21B, 22A, and 22B can be of any desired shape and dimension.

Fig. 3 is a section view of the polishing pad means 19 and semiconductor wafer 23 of Fig. 2 further detailing construction details thereof. The wafer 23 includes a macroscopically planar subsurface 35. Features 31, 32, 33, 34, 36 and 38 are each connected to subsurface 35 and extend a substantially equal distance away from subsurface 35. Features 31 to 34 each represent a metal line or strip formed on subsurface 35 using the photolithography process earlier described. An alternate method of forming features which are connected to subsurface 35 is to form trenches 36 and 38. In Fig. 3 coating layer 30 extends over and covers features 31 to 34, 36, 38 and covers subsurface 35. The high areas of coating 30 which "mound" or extend over features 31 to 34 abrade at a different rate than the low areas of coating 30 intermediate features 32 and 32, 32 and 33, etc. The minimum thickness, represented by arrows T, of coating layer 30 is greater than the distance which each feature 31 to 34 extends away from subsurface 35. Since features 31 and 34 are generally of equal shape and dimension, this means that the work surface 23B is at all points a greater distance from subsurface 35 than are the uppermost portions of features 31 to 34. The shape and dimension of each trench 36 and 38 is generally equivalent to the shape and dimension of each feature 31 to 34. It is understood that features 31 to 34, 36, 38 can be of any desired shape and dimension. The polishing apparatus of the invention is, however, particularly useful when it is necessary to planarize work surface 23B

- 9 -

to remove a sufficient thickness of coating 30 to expose only the tips or outermost parts of features 31 to 34. In so removing a portion of coating 30, it is desired that the resulting polished surface of coating 30 be flat, i.e., be planarized, and generally conform to the shape and dimension of the macroscopically flat subsurface 35. For the purposes of discussion, the undulation in subsurface 35 and work surface 23B is, in Fig. 3, greatly exaggerated.

In Fig. 2, when the resilient pads 22 and 21 are pressed in the direction of arrow S against work surface 23B (or vice-versa), the pads 22 and 21 are compressed. The force generated against point B on surface 23B by pads 22 and 21 will be less than the force generated by compressed pads 22 and 21 against point A on surface 23B, simply because pads 22 and 21 are compressed more by surface 23B at point A than at point B. Similarly, in Fig. 3, the forces F1 and F2 acting against surface 23B are greater than the forces F3 and F4 acting against surface 23B, again because the pad portions producing forces F1 and F2 are more greatly compressed than the pad portions producing forces F3 and F4. In Fig. 3, polishing surface 22B rotates over work surface 23B. An aqueous colloidal suspension of silica, alumina or other abrasive is on polishing surface 22B and gradually polishes and planarizes work surface 23B. The rotation of polishing surface 22B with respect to work surface 23B is illustrated in Fig. 7. In Fig. 7 circular surface 22B rotates in the direction of arrow W. Stationary head 24 presses work surface 23B against polishing surface 22B. Head 24 can, if desired, rotate or otherwise move with respect to surface 22B.

The objective of polishing pad means 19 is to produce a macroscopically flat surface which has a contour generally conforming to the contour of subsurface 35, or, alternatively, to produce a polished surface on coating 30 which is substantially microscopically flat or

- 10 -

planar to within plus or minus 200 to 500 Angstroms total indicator runout (T.I.R.) of a square portion of surface area 23B which is four millimeters by four millimeters, i.e., which has an area of sixteen square millimeters. A  
5 T.I.R. of 200 Angstroms means that there is a difference of 200 Angstroms between the lowest point and the highest point on the surface within the sixteen square millimeter area of surface 23B. A T.I.R. in the range of 200 to 500 Angstroms is generally equivalent to a plus or minus  
10 deviation of 100 to 250 Angstroms from the median plane of the sixteen square millimeter area. While the apparatus of the invention has produced a T.I.R. of 200 to 500 Angstroms in a sixteen square millimeter area, the apparatus is preferably used to produce a T.I.R. of 200  
15 to 500 Angstroms in square portion of surface area 23B which has an area of at least four square millimeters. It is desired to eventually achieve with the invention or with improved embodiments thereof a T.I.R. of 200 to 500 Angstroms over a surface area of 23B which is twenty  
20 millimeters by twenty millimeters, i.e., which has an area of 400 square millimeters. Problems are encountered in polishing coating 30 because features 31 to 34 often have a different hardness or polishing properties than the material comprising coating 30. If, for example,  
25 coating 30 abrades more readily than features 31 and 32, the area of coating intermediate features 31 and 32 may tend to scour out and form a depressed area intermediate features 31 and 32. Another important problem encountered in polishing coating 30 is that because coating 30 is  
30 very thin, typically two to three microns thick, it is important that polishing surface 22B conform to the global undulations inherent in the surface 23B of coating 30. Such global undulations are on the order of 0.1 to about 4.0 microns from median plane 15 and are  
35 represented by arrows F and G in Fig. 4. The high spots caused by features 31 to 34 only occupy a small area in the global undulations of surface 23B. Since coating 30

- 11 -

is of a generally uniform thickness, the global undulations of surface 23B generally are parallel to and conform to the global undulations in surface 35. If surface 22B were perfectly flat and perfectly rigid, then in Fig. 3 the portion of coating 30 covering feature 31 could be completely polished off of subsurface 35 along with feature 31 while none of the coating covering features 33 and 34 would be removed. The polishing apparatus of the invention minimizes or prevents the scouring of softer material from the surface of a semiconductor material and, importantly, prevents or minimizes the removal of material from global undulations which are intermediate high (or low) points in the work surface of the semiconductor material. For example, when the distance between high features 31 and 34 is 500 to 600 microns or less, features 31 and 32 are metal lines, and coating 30 is an insulative metal oxide or other material which is harder or softer than or is of the same hardness as features 31 and 32, the polishing apparatus of the invention typically produces a planarized surface which extends between the outermost tips of features 31 and 32 and is flat to within 200 to 300 Angstroms.

In the practice of the invention, the resilient layer 22 of the polishing pad means 19 is stiffer than layer 21 and has a deflection constant,  $D$ , in the range of 0.25 to 3.0 microns per psi when a compressive force in the range of four psi to twenty psi is applied to the layer 21. The resilient layer 21 has a deflection constant of 6.0 microns per psi or greater. The deflection constant of layer 21 presently preferably is in the range of 6.0 to 12.0 microns per psi when a compressive force in the range of four psi to twenty psi is applied to the layer 21. Ordinarily, the deflection constant represents the slope of the linear or generally linear portion 12 of line 13 in Fig. 1. The high deflection constant of layer 21 permits layer 21 to elastically deform to high areas and low areas on the

- 12 -

surface of coating 30. The low deflection constant of layer 22 helps to prevent scouring of soft material from work surface 23B, for instance, from between features 31 and 32. The lower deflection constant, D, of layer 22 promotes the bridging by layer 22 of areas such as the area intermediate features 31 and 32. As earlier noted, pad 22 effectively bridges areas which are spaced a distance apart, indicated by arrows E in Fig. 3, that is up to about 500 to 600 microns. Urethane foams and other types of foam or elastic materials can be utilized in the practice of the invention as long as the desired deflection constant values are obtained.

In arriving at the pad composition of the invention, I believe it was important to recognize certain characteristics of the type of polishing being accomplished and of the materials utilized in the polishing pad. First, the primary purpose of polishing the work surface of a coating 30 is planarization. This contrasts to the primary purpose of smoothness common to many polishing operations. Second, the polishing apparatus of the invention is designed to simultaneously contact all or most of the points on a macroscopically flat surface of a piece of material to polish and planarize the surface. This type of polishing is distinguishable from other polishing operations which polish a limited area of a piece of material and, accordingly, constitute a point contact type of polishing. Third, a critical property of the composite polishing pad of the invention is the deflection constant, D, of the resilient layers of material utilized in the pad. It is sometimes thought that the deflection constant of a piece of material is indicated by the melting point, density, pliability, hardness, or other physical properties of the material. This assumption is not correct, as is in part demonstrated by the comparison of physical properties in TABLE I below.

- 13 -

	Plastic	Specific Gravity	Modulus of Elasticity	Rockwell Hardness
5	Phenol-formaldehyde (asbestos filled)	1.70	18.8	R-100
	Furfuryl alcohol (asbestos filled)	1.70	15.8	R-100
10	Polyvinyl chloride (unplasticized)	1.40	4.5	R-120

15 In the above table the modulus of elasticity of phenlon-formaldehyde is significantly different from the modulus of elasticity of furfuryl alcohol even though the hardness of each identical. Also, even though the density of polyvinyl chloride is less than that of furfuryl alcohol, the hardness of polyvinyl chloride is greater than the hardness of furfuryl alcohol.

20 The modulus of elasticity is the ratio of stress to strain and is a measure of how well a solid resists deforming forces.

25 In Fig. 7, the portion of pad 22 following path P1 is compressed under wafer 23 for a longer period of time during each rotation of pad 22 than is portion of pad 22 which follows path P2. Regardless, however, of whether the pad 22 follows path P1 or P2, the time required to compress pads 21 and 22 (See also Figs. 3 and 4) beneath wafer 23 is generally about the same. This is more specifically illustrated in Fig. 5, where the time required to compress the flexible pads comprising polishing pad means 19 is indicated by the time required for pads 21 and 22 to move distance D4. After polishing surface 22B contacts the rounded edge 50 of wafer 23 and moves the distance indicated by arrows D4 under wafer 23, the surface of pad means 19 is compressed a distance indicated by arrows D3. A typical time for surface 22B to be compressed distance D3 is in the range of 0.001 to

- 14 -

0.003 seconds, typically about 0.002 seconds. Such a time could, however, be as low as about 0.0003 seconds. The distance of D3 presently equals about 70 microns. A 70 micron compression in 0.002 seconds roughly translates to a compression rate of about one inch per second. With velocity of movement or compression, the stiffness of a piece of material increases and the force required to compress the material increases. The graph in Fig. 6 reflects this phenomena. At a time equal to zero seconds in Fig. 6, point 60 is just at the outer edge of wafer 23 and is beginning to move underneath work surface 23B of wafer 23. At a time equal to 0.002 seconds in Fig. 6, point 60 on pad means 19 has moved a distance D4 underneath wafer 23 and the resilient pads 21 and 22 have been compressed a distance indicated by arrows D3. At the time point 60 has moved distance D4 under wafer 23, the force of the pad means 19 acting against wafer 23 is, as I presently theorize it, at a maximum value indicated by point 61 in Fig. 6. As point 60 on pad means 19 continues to move beneath wafer 23, the force generated by the compressed pads 21 and 22 against wafer 23 gradually reduces until after point 60 of the pad means 19 has been under wafer 23 for 0.1 seconds the force generated by pad means 19 against wafer 23 at point 60 is indicated by point 62 in Fig. 6. This increase in the force generated by pad means 19 against wafer 23 with an increase in the velocity of compression of pads 21 and 22 mitigates against the use of elastic materials having a high deflection constant and, accordingly, a greater thickness. On the other hand, a high deflection is desirable because it enhances the ability of pad 21 to quickly react and conform to undulations in the working surface 23B of wafer 23 while maintaining a more uniform pressure against the wafer 23.

Another problem associated with elastic pads fabricated from foam or other materials is hysteresis. Hysteresis is the tendency of a pad, after compressive

- 15 -

pressure is released from the pad, not to elastically expand completely to its original shape.

5 In order to minimize the problem of hysteresis and to minimize the increase in force which occurs with an increase in the velocity of compression of an elastic  
10 pad material, I have discovered the composite pad shown in Fig. 8. The pad includes resilient foam material 22 having a deflection constant much lower than the deflection constant of the "pad" formed by the mass of  
15 gas filled bubbles positioned beneath pad 22. Air, nitrogen or any other desired gas can be included in each elastic bubble 70. Bubbles 70 can be interconnected or be separate and stacked on one another. One or more bubbles 70 can be utilized. Each bubble 70 completely  
20 encapsulates the gas or other fluid contained in the bubble. If desired, a first elastic bubble 70 can be interconnected with a second adjacent elastic bubble 70 such that the interconnection permits gas to flow between the bubbles and such that neither bubble completely  
25 encapsulates the gas in the bubble. Consequently, when the first bubble was compressed, gas would tend to be forced from the first bubble into the second bubble. The gas in bubbles 70 minimizes the increase in force which results with an increase in the velocity of compression and also minimizes the effects of hysteresis. As would be  
30 appreciated by those of skill in the art, bubbles 70 can be removed from cylindrical chamber 71, chamber 71 filled with a gas, and pad 22 sealingly slidably engaged with the upper portion of chamber 71 in the fashion of a piston such that when pad 22 is pressed downwardly in the direction of arrow X, the air in chamber 71 is compressed and forces the pad surface 22B into substantial  
comformance with the globally undulating wafer surface.

35 Having described my invention in such terms as to enable those skilled in the art to understand and practise it, and having identified the presently preferred embodiments thereof, I Claim:

- 16 -

1. Apparatus for polishing a piece of material including

a macroscopically flat subsurface,  
at least a pair of features

each connected to said  
subsurface,

each extending a substantially  
equal distance away from said  
subsurface,

being spaced apart a distance of  
less than five hundred microns,

a coating extending over and covering  
said features and said subsurface, the  
upper surface of said coating  
comprising a work surface which is  
macroscopically flat and  
microscopically undulating,

said apparatus microscopically planarizing  
said work surface to expose said pair of  
features, said apparatus comprising

(a) polishing pad means including

(i) a base,

(ii) a first layer of resilient  
material connected to said base  
and having an outer surface  
spaced apart from said base and  
having a deflection constant  
which is greater than six microns  
per psi when a selected  
compressive pressure in excess of  
about four psi is applied to said  
first layer,

(iii) a second layer of resilient  
material connected to at least a  
portion of said outer surface,  
having a polishing surface spaced  
apart from said outer surface,

- 17 -

and having a deflection constant less than the deflection constant of said first layer when said selected compressive pressure is applied to said second layer,

(iv) a colloidal slurry polishing media on said polishing surface of said second layer;

(b) holding means for holding said piece of material with said work surface disposed against said polishing surface; and,

(c) motive power means for moving at least one of said polishing pad means and said holding means with respect to the other of said pad means and said holding means such that movement of said one of said polishing pad means and said holding means causes said colloidal media and said polishing surface to contact and polish said work surface.

2. Apparatus for polishing a piece of material including

a macroscopically flat work surface, and,

first and second adjoining areas in said surface, said first area abrading at a different rate than said second area,

said apparatus comprising,

(a) polishing pad means including

(i) a base,

(ii) a first layer of resilient material connected to said base and having an outer surface spaced apart from said base and

- 18 -

- 5 having a deflection constant which is greater than about six microns per psi when a selected compressive pressure in excess of about four psi is applied to said first layer of material,
- 10 (iii) a second layer of resilient pliable material connected to at least a portion of said outer surface, having a polishing surface spaced apart from said outer surface, and having a deflection constant less than about three microns per psi when said selected compressive pressure is applied to said second layer of material,
- 15 (iv) a colloidal slurry polishing media on said polishing surface of said second layer;
- 20 (b) holding means for holding said piece of material with said work surface disposed against said polishing surface; and,
- 25 (c) motive power means for moving at least one of said polishing pad means and said holding means with respect to the other of said polishing pad means and said holding means such that movement of said one of said polishing pad means and said holding means causes said colloidal media and said polishing surface to contact and polish said work surface;
- 30
- 35 said apparatus polishing said first area and said second area of said work surface such that said first area and said second

- 19 -

area deviate at all points from the median plane passing through said first area and said second area by an amount less than 500 Angstroms.

- 5                   3. Apparatus for polishing a work surface of a piece of material, said work surface being macroscopically flat, and
- 10                   generally microscopically flat such that said work surface deviates at all points from the median plane passing through said work surface by an amount less than about four microns,
- 15                   said apparatus planarizing said work surface and comprising
- (a) polishing pad means including
- (i) a base,
- (ii) a first layer of resilient material connected to said base and having an outer surface spaced apart from said base and having a deflection constant which is greater than six microns per psi when a selected compressive pressure in excess of about four psi is applied to said first layer of material,
- 25                   (iii) a second layer of resilient material connected to at least a portion of said outer surface, having a polishing surface spaced apart from said outer surface, and having a deflection constant less than the deflection constant of said first layer when said selected compressive pressure is applied to said second layer of material,
- 30
- 35

- 20 -

- (iv) a colloidal slurry media on said polishing surface of said second layer;
- (b) holding means for holding said piece of material with said work surface disposed against said polishing surface; and,
- (c) motive power means for moving at least one of said polishing pad means and said holding means with respect to the other such that movement of said one of said polishing pad means and said holding means causes said colloidal media and said polishing surface to contact and polish said work surface.
4. The apparatus of Claim 2, wherein the total combined area of said first and second areas is less than sixteen square millimeters.

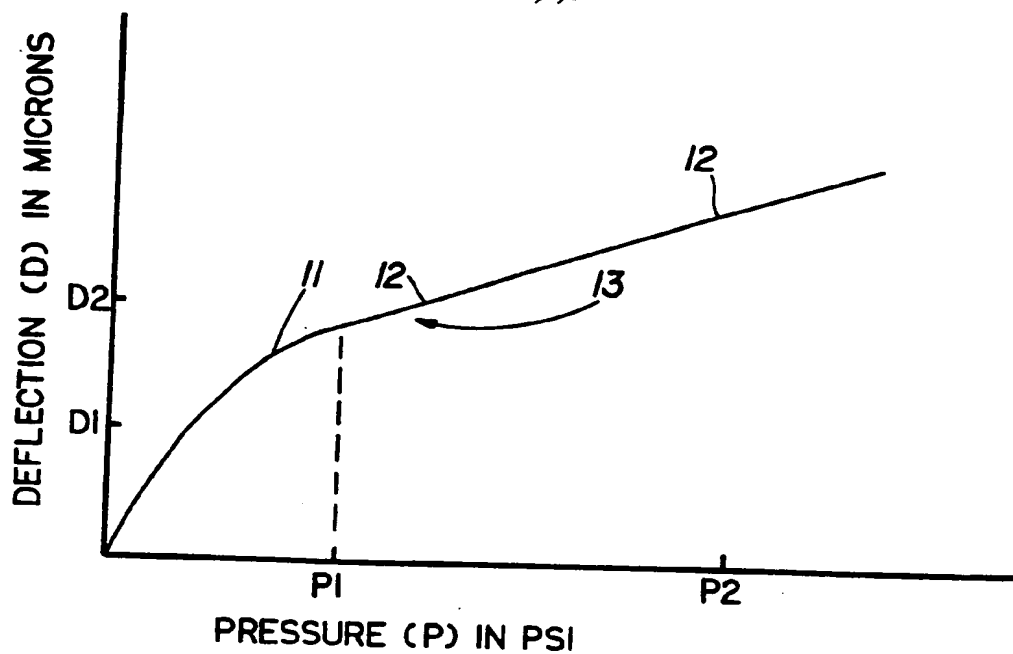


FIG. 1

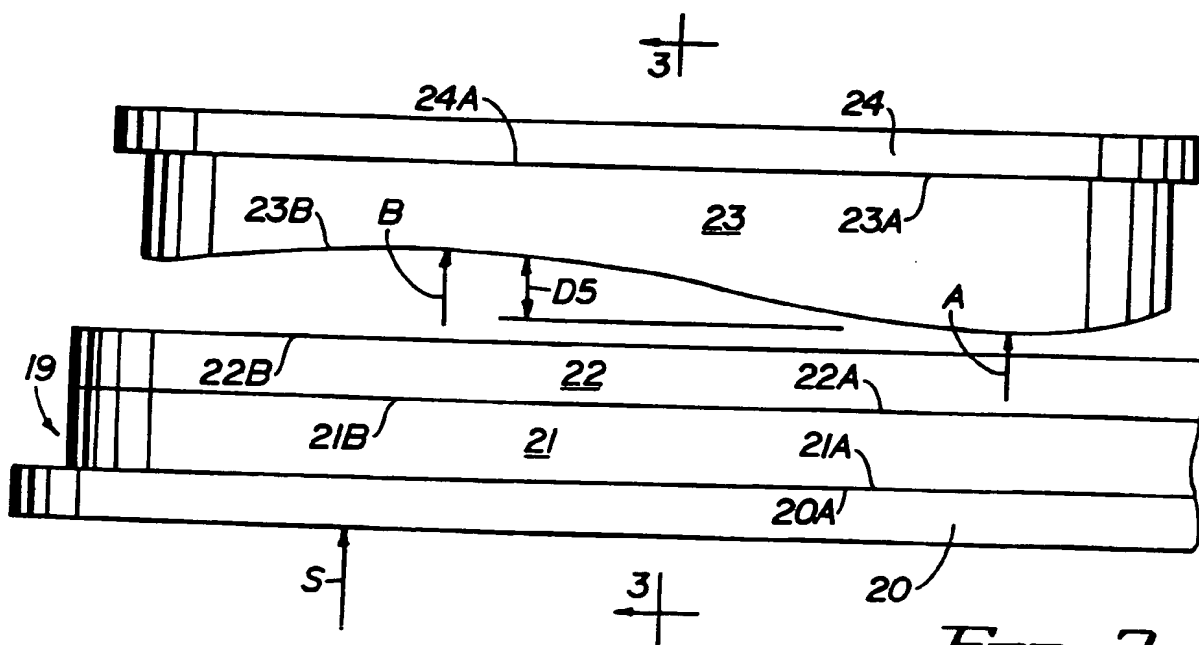


FIG. 2

2/4

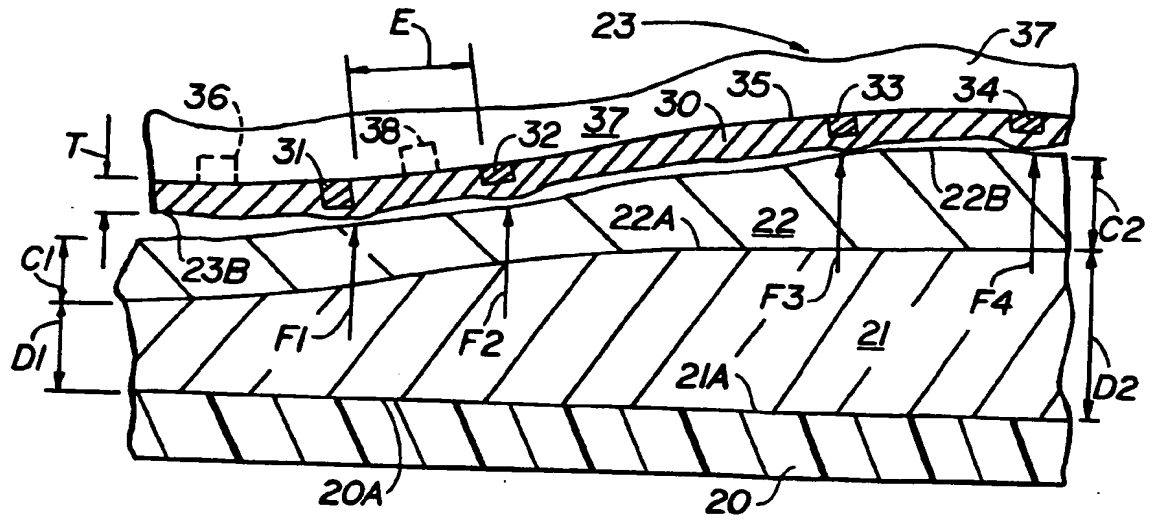


FIG. 3

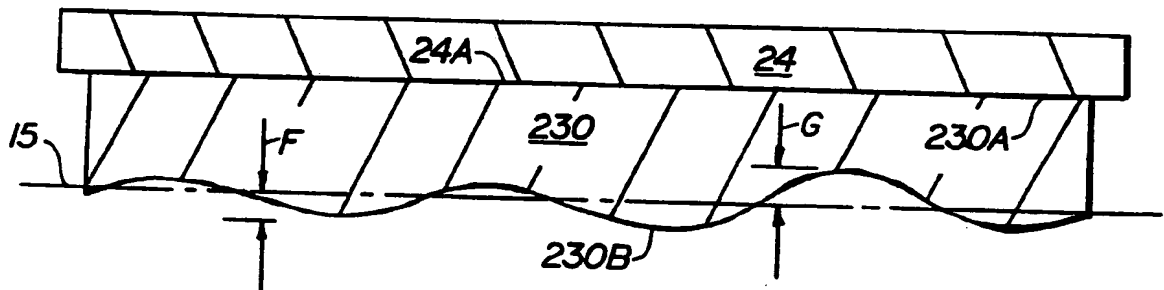


FIG. 4

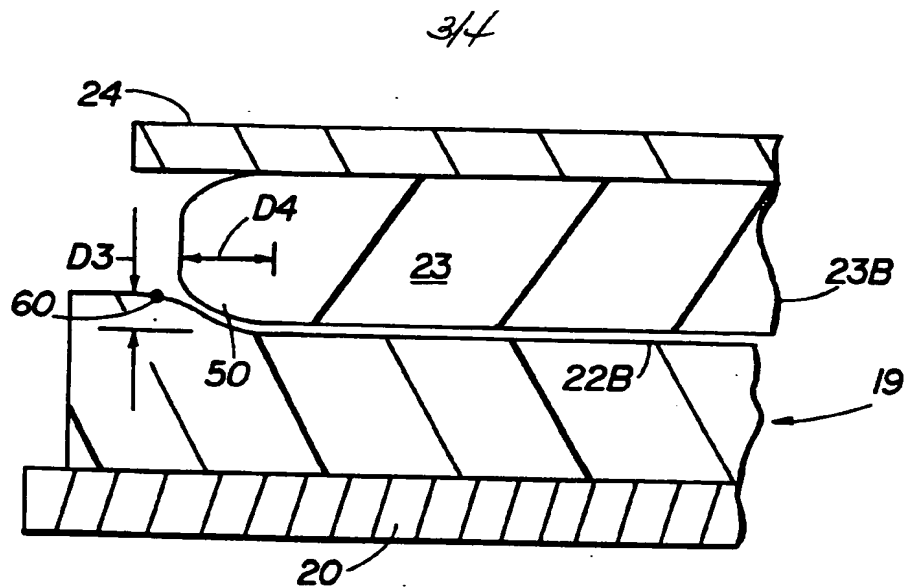


FIG. 5

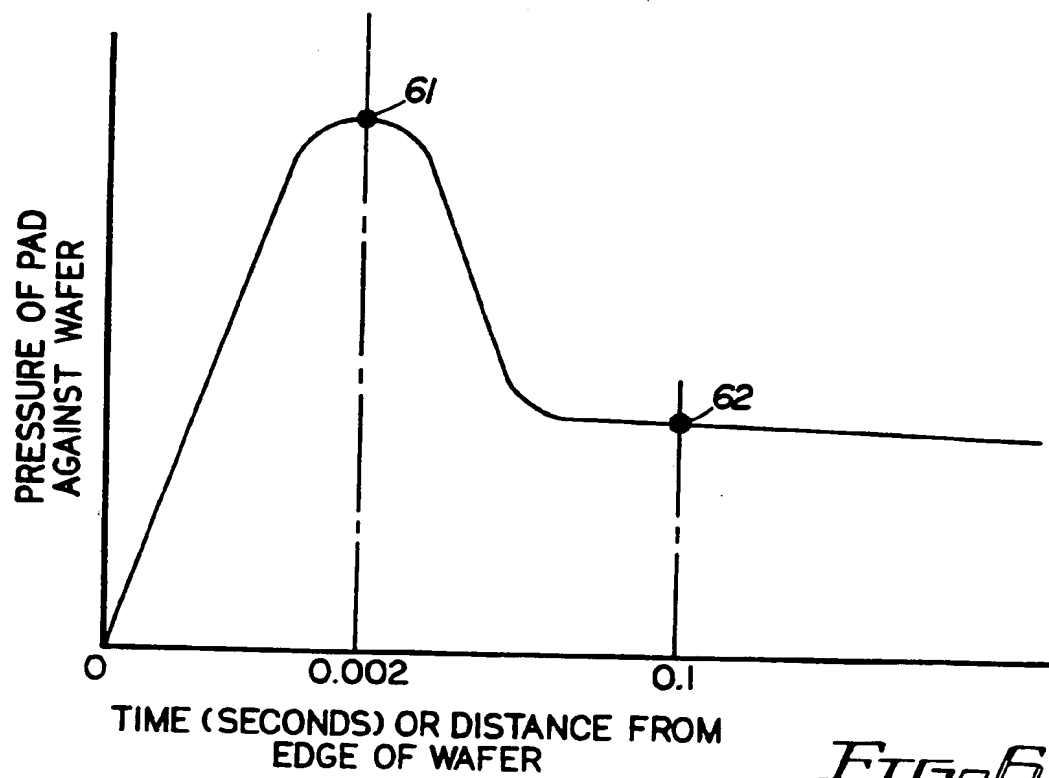
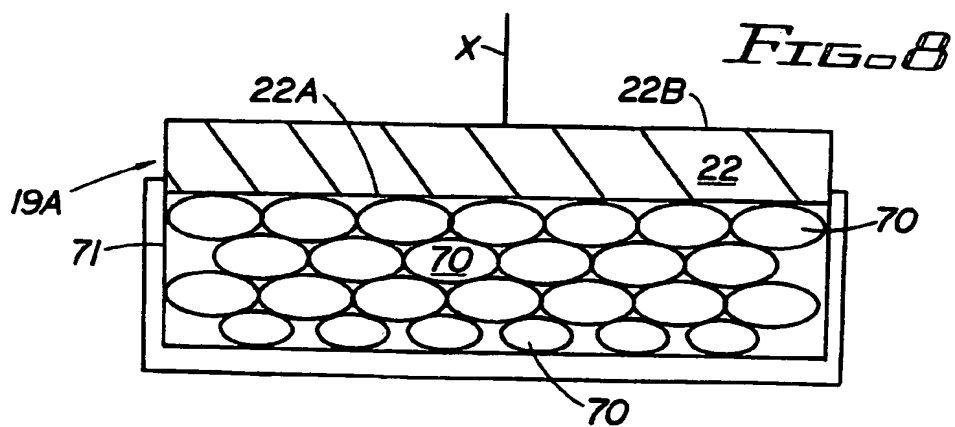
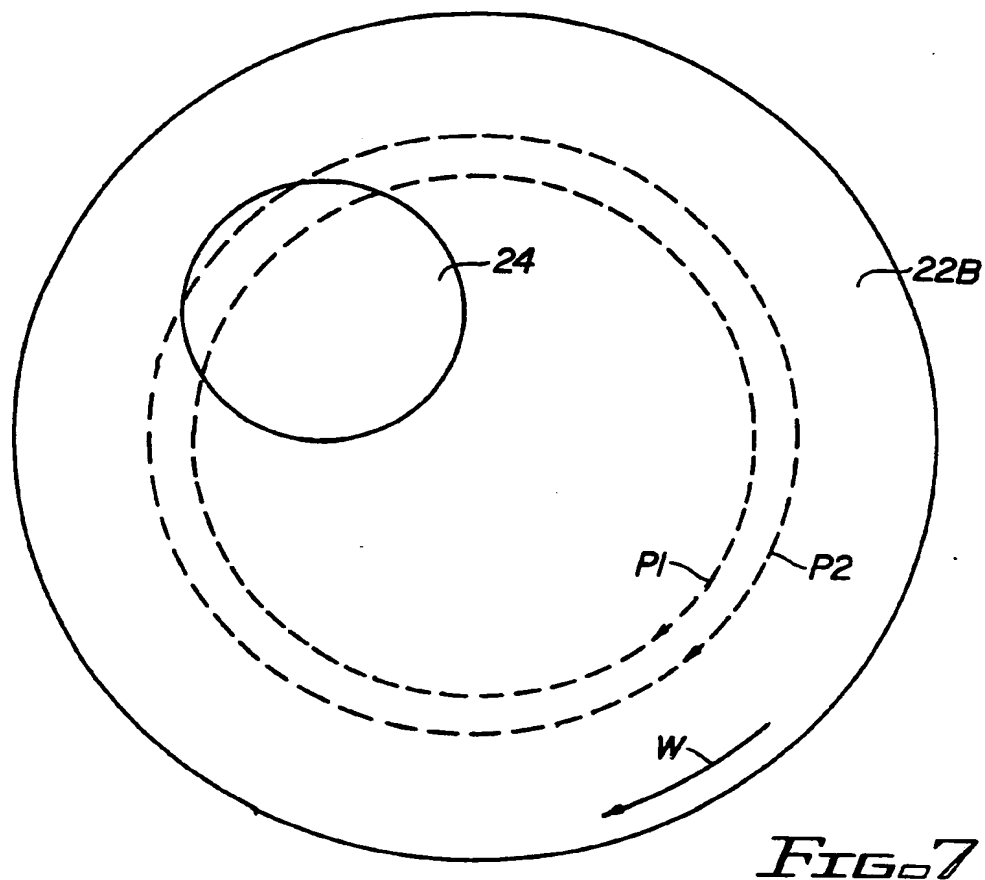


FIG. 6


4/4



## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 91/01945

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5                      B24B37/04		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int.Cl. 5	B24B ;                      B24D ;                      H01L	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 190 (M-704)(3037) 03 June 1988, & JP-A-62 297064 (RODEELE NITTA K.K.) 24 December 1987, see the whole document ---	1-3
A	US,A,3504457 (H.R.JACOBSEN ET AL) 07 April 1970 see the whole document (cited in the application) ---	1-3
A	FR,A,2125019 (PHILIPS GLOEILAMPENFABRIEKEN N.V.) 22 September 1972 ---	
<p><sup>10</sup> Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
09 JULY 1991	22. 07. 91	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	ESCHBACH D.P.M. 	

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

**US 9101945  
SA 46195**

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**09/07/91**

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		FR-A-	1528216	
		GB-A-	1152165	14-05-69
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		DE-A-	2164958	17-08-72
		GB-A-	1315646	02-05-73
		NL-A-	7101327	04-08-72
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